**NUCLEOBASES AND OTHER PREBIOTIC SPECIES FROM THE ULTRAVIOLET IRRADIATION OF PYRIMIDINE IN ASTROPHYSICAL ICES.** S. A. Sandford[1], M. Nuevo[1,2], C. K. Materese[1,2], and S. N. Milam[3], [1]NASA Ames Research Center, MS 245-6, Moffett Field, CA 94035, USA (Scott.A.Sandford@nasa.gov), [2]SETI Institute, 189 N. Bernardo Ave., Ste. 100, Mountain View, CA 94043, USA, [3]NASA Goddard Space Flight Center, MS 691.0, Greenbelt, MD 20771, USA.

**Introduction:** Nucleobases are *N*-heterocycles that are the informational subunits of DNA and RNA, and are divided into two families: pyrimidine bases (uracil, cytosine, and thymine) and purine bases (adenine and guanine). Nucleobases have been detected in meteorites [1,2] and their extraterrestrial origin confirmed by isotope measurement [3]. Although no *N*-heterocycles have ever been observed in the ISM [4,5], the positions of the 6.2-μm interstellar emission features suggest a population of such molecules is likely to be present [6]. In this work we study the formation of pyrimidine-based molecules, including nucleobases, as well as other species of prebiotic interest, from the ultraviolet (UV) irradiation of pyrimidine in combinations of $H_2O$, $NH_3$, $CH_3OH$, and $CH_4$ ices at low temperature, in order to simulate the astrophysical conditions under which prebiotic species may be formed in the interstellar medium and icy bodies of the Solar System.

**Experimental:** Gas mixtures are prepared in a glass mixing line (background pressure ~$10^{-6}$–$10^{-5}$ mbar). Relative proportions between mixture components are determined by their partial pressures. Gas mixtures are then deposited on an aluminum foil attached to a cold finger (15-20 K) and simultaneously irradiated with an $H_2$ lamp emitting UV photons (Lyman α and a continuum at ~160 nm). After irradiation samples are warmed to room temperature, at which time the remaining residues are recovered to be analyzed with liquid and gas chromatographies.

**Results:** These experiments showed that the UV irradiation of pyrimidine mixed in these ices at low temperature leads to the formation of several photoproducts derived from pyrimidine, including the nucleobases uracil [7,8] and cytosine [8], as well as their precursors 4(3*H*)-pyrimidone and 4-aminopyrimidine [7,8] (Fig. 1). Theoretical quantum calculations on the formation of 4(3*H*)-pyrimidone and uracil from the irradiation of pyrimidine in pure $H_2O$ ices are in agreement with their experimental formation pathways [9]. In those residues, other species of prebiotic interest such as urea and the amino acids glycine and alanine could also be identified [8]. However, no pyrimidine derivatives containing $CH_3$ groups, including the third nucleobase thymine, could be identified [10], suggesting that the addition of methyl groups to pyrimidine is not an efficient process [10].

**References:** [1] van der Velden W. and Schwartz A., (1977) *Geochim. Cosmochim. Acta*, 41, 961. [2] Stoks P. and Schwartz A. (1979) *Nature*, 282, 709. [3] Martins Z. et al. (2008) *Earth Planet. Sci. Lett.*, 270, 130. [4] Kuan Y.-J. et al. (2003) *Month. Not. R. Astron. Soc.*, 345, 650. [5] Charnley S. B. et al. (2005) *Adv. Space Res.*, 36, 137. [6] Hudgins D. M. et al. (2005) *Astrophys. J.*, 632, 316. [7] Nuevo M. et al. (2009) *Astrobiology*, 9, 683. [8] Nuevo M. et al. (2012) *Astrobiology*, in press. [9] Bera P. P. et al. (2010) *J. Chem. Phys.*, 133, 104303. [10] Materese C. K. et al. (2012) *Astrobiology*, in preparation.

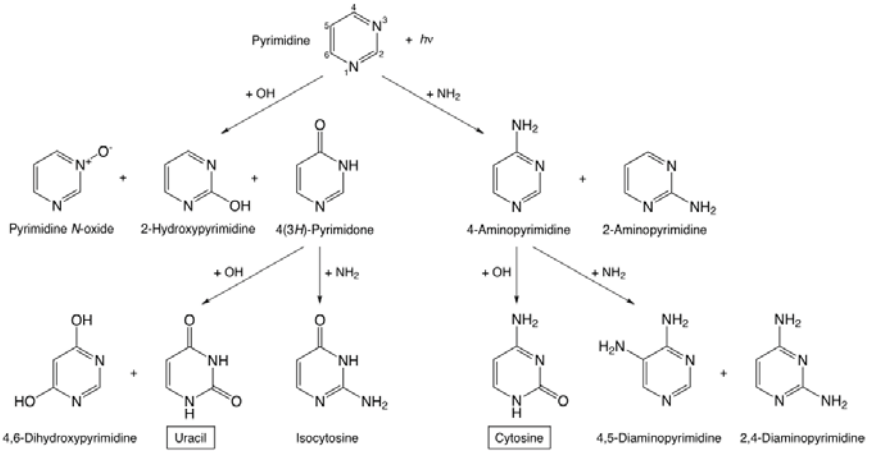


*Fig. 1: Pyrimidine derivatives formed after addition of OH groups from $H_2O$ and $NH_2$ groups from $NH_3$. Photochemistry with $CH_3OH$ is similar to that of $H_2O$, with additional compounds such as 4-pyrimidinemethanol.*